MAMMOTH TRUMPET

Volume 29, Number 4 | Center for the Study of the First Americans | Department of Anthropology
October, 2014 | Texas A&M University, 4352 TAMU, College Station, TX 77843-4352 | ISSN 8755-6898

World Wide Web site http://centerfirstamericans.org and http://anthropology.tamu.edu

Spread of Wapiti Mimics the Migration of Ancient Humans

INSIDE

ANTHROPOLOGISTS seeking to confirm the origins of Native Americans got a huge boost from two ancient burials. Ancient DNA recovered from the remains of a boy buried at the Mal'ta site in Siberia 24,000 years ago identified him as the ancestor of modern populations in the Americas; and the DNA of a Clovis child buried at the Anzick site in Montana 12,700 years ago revealed that 80% of Native Americans are direct descendants of the child's extended family, and that humans first entered the Americas "a few thousand years before Clovis" (**MT 29-2,** "Ancient Siberian Boy Reveals Complex Origins of First Americans" and "Clovis Child Answers Fundamental Questions about the First Americans"). These two milestone dates, spanning nearly 12,000 years, bracket the likely first major entry of humans into the New World.

Efforts to determine precise details of the migration from Siberia into North America, however—the route taken, the timing of sequential phases of the migration and their underlying causes, the availability of resources, the state of the changing environment of the terminal Pleistocene—have been frustrated by the paucity of known human occupations dating to the Pleistocene. To circumvent this deficit of human evidence, a group of 13 scientists from across the globe, led by Ian Barnes of the Natural History Museum in London, UK, are exploring the theory that tracking wapiti (North American elk) can shed light on barriers and corridors to human migration across the Bering Strait during this time period.

"Wapiti were a previously unrecognized part of the large-mammal fauna of the high arctic region until only 500 years ago," says Barnes. What's important is that wapiti were among the few large mammals that successfully migrated into the Americas at about the same time as humans toward the end of the Last Glacial Maximum.

JESSICA THOMAS

Barnes, 2011.

Pleistocene, a period of erratic changes

Global cooling during the Pleistocene expanded glaciers, which thereby lowered the sea level and connected land masses around the globe. The Bering Strait was one such region where receding water levels created a land bridge between northeast Siberia (western Beringia, from the Verkhoyansk Mountains and Lena River basin) and Alaska (eastern Beringia, extending to the Northwest Territories of Canada). "Our best guess," says Barnes, "is that the environment on the land bridge shifted from cold and wet to somewhat warmer and drier, with plants that would have been better for browsers and mixed feeders such as elk."

Evidence of humans in the Americas is a patchwork quilt of apparently random dates. Dating by optically stimulated luminescence confirms human presence at the Friedkin site in central Texas sometime after 15,500 years ago (**MT 27-2,** "Buttermilk Creek: A Pre-Clovis Occupation along the Margin of the Southern High Plains"). The few known sites farther to the north, however, which might seem the most likely point of human entry into the New World, appear to be at least 1,000 years younger. Swan Point, for example, the earliest known human occupation in Alaska, dates to

The Mammoth Trumpet (ISSN 8755-6898) is published quarterly by the **Center for the Study of the First Americans,** Department of Anthropology, Texas A&M University, College Station, TX 77843-4352. Phone (979) 845-4046; fax (979) 845-4070; e-mail csfa@tamu.edu. Periodical postage paid at College Station, TX 77843-4352 and at additional mailing offices.

POSTMASTER: Send address changes to:

Mammoth Trumpet
Department of Anthropology, Texas A&M University
4352 TAMU
College Station, TX 77843-4352

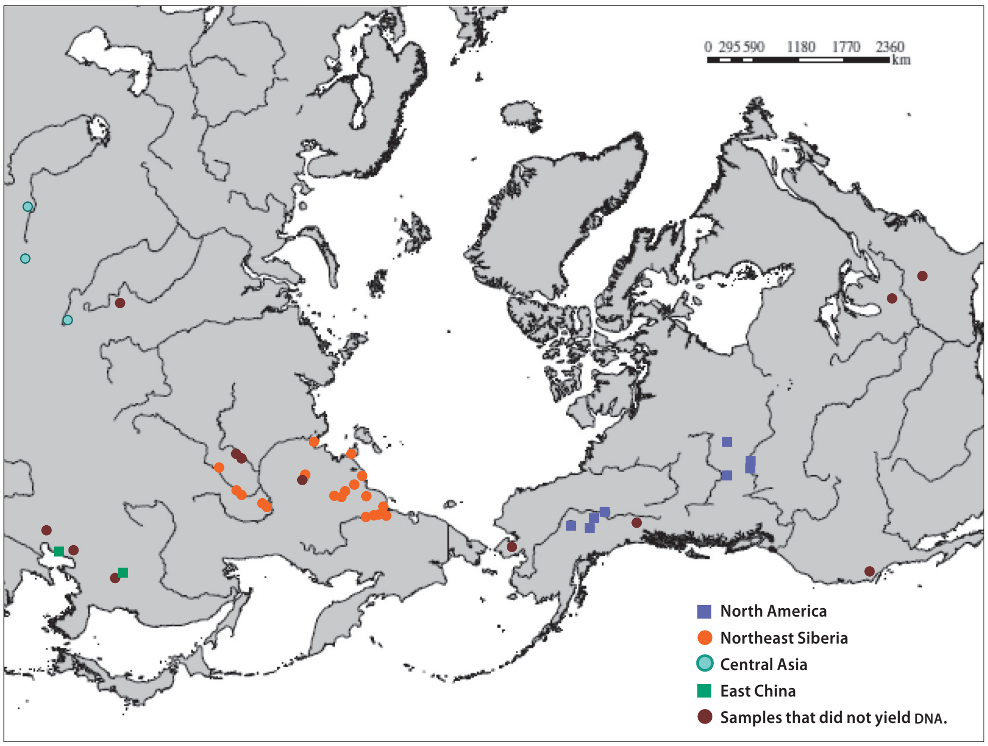
Mammoth Trumpet, Statement of Our Policy

Many years may pass between the time an important discovery is made and the acceptance of research results by the scientific community. To facilitate communication among all parties interested in staying abreast of breaking news in First Americans studies, the **Mammoth Trumpet**, a science news magazine, provides a forum for reporting and discussing new and potentially controversial information important to understanding the peopling of the Americas. We encourage submission of articles to the Managing Editor and letters to the Editor. Views published in the **Mammoth Trumpet** are the views of contributors, and do not reflect the views of the editor or **Center** personnel.

–Michael R. Waters, Director

14.4 ka (14,400 years ago) (**MT 24-1,** “Clues from the Ashes: A Closer Look at Swan Point”). “Presumably, there was a range of human cultural groups migrating into the New World at this time, and the Swan Point inhabitants were just one of them,” says Barnes. “This flags up the piecemeal nature of the archaeological record.”

In the absence of archaeological evidence, Barnes’s team therefore turned their attention to large-mammal species that migrated along similar routes across Beringia. Previous work had established some of the patterns of faunal migration into the Americas. Brown bears have been shown to be present in Alaska until a regional extinction during MIS 3 (Marine Isotope Stage 3, ca. 5724 ka), and were subsequently reestablished at 25 ka. The Pleistocene lion seems to have followed a similar pattern, with an excess of fossil remains in Alaska dating to about 25 ka. Wapiti and moose, on the other hand, first appear in the fossil record of North America at 15 ka, about the same time as the first known human occupations in Alaska. Because their migratory routes and dates are traceable by abundant unambiguous fossils, these large mammals may serve as reliable proxies for determining the timing and mode of human expansion into the New World.



AFTER ROYALSOCIETYPUBLISHING

Approximate locations of ancient *Cervus* remains sampled in the study.

Enter the wapiti

The study focused on wapiti (*Cervus elaphus canadensis*) specimens, from the late Pleistocene to modern times, from Siberia, Alaska, and the rest of North America. Modern wapiti, native to temperate to boreal regions, are normally found at latitudes below 60° N. Barnes’s team therefore assumed that the animals dispersed quickly into North America during a short period of relatively mild climate. To their surprise, however, they found that wapiti had previously occupied northeast Siberia for over 50,000 years and expanded across the land bridge only toward the end of the Pleistocene.

Analyzing ancient DNA revealed that only a part of the Siberian population migrated into Alaska when the land bridge became passable; like the human population, another part of the wapiti population stayed behind. This finding agrees with the proposal that human migration may have occurred in several discrete stages.

Collecting samples

Museums across Asia and North America contributed 113 samples of ancient antlers, teeth, and bones, which were compared with 74 modern specimens from the same locations. In order to best pin down the origins of the North American wapiti population, the team included the extinct subspecies *Cervus elaphus merriami,* Sika deer, Bukhara deer, and a range of European red deer.

To establish that the first migration of wapiti into the New World occurred around 15 ka, the team examined a number of wapiti bones that had been dated before this time period in previous studies. None of these gave results for DNA analysis, and so five were analyzed by Matthew Collins’s group in York, UK, using ZooMS (zooarchaeology by mass spectrometry), a method that identifies taxonomy by means of diagnostic collagen markers. Of the four that yielded collagen, only one was identified as possible cervid; this was dated to 13.1 ka—a date commensurate with terminal-Pleistocene colonization. Two of the other samples were identified as bovid (possibly bison), and one sample from Tennessee turned out to be horse. Thus the team is highly confident that wapiti and humans migrated across Beringia at approximately the same time.

Analyzing the data

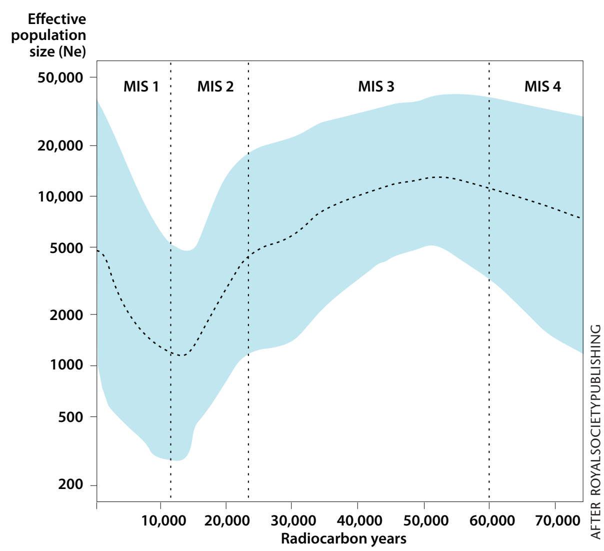
Dating of the Siberian bones by the Oxford Radiocarbon Accelerator Unit revealed that wapiti were present in northeast Siberia throughout the late Pleistocene, and that the population persisted until about 500 years ago. This suggests that wapiti are a more flexible species than previously thought, with a long late-Pleistocene and Holocene history in the Arctic. To confirm that the bones they had dated were definitely of northeast Siberian origin, Noreen Tuross of Harvard analyzed oxygen isotopes of 16 of the bones. This study verified that the animals had lived in the latitude of the high arctic and thus eliminated the possibility that the material was redeposited or incorrectly labeled during storage. Finally, DNA was extracted from an-

MAMMOTH TRUMPET

cient specimens and recent museum specimens in separate laboratories to avoid contaminating ancient DNA. The DNA of 44 of the 113 ancient samples and of 49 of the 74 recent samples was successfully amplified and sequenced.

Intensive DNA studies of the entire range of individuals from northeast Siberia, Alaska, and central and east Asia identified two main groups. The first represents a diverse group of modern wapiti from central Asia, northeastern China, and eastern Russia. A small number of DNA sequences present in this group were found in the Siberian specimens, suggesting a low level of migration from central eastern Asia into Beringia during MIS 3 (ca. 5724 ka).

The second group includes modern American wapiti, central Asian individuals, and ancient specimens from Beringia and Alberta. Whereas specimens of the first group show great diversity, all modern North American specimens are genetically very similar to one another, to ancient wapiti from Alaska, and to a subset of those from northeast Siberia. The data strongly support the expansion of a subset of wapiti from northeast Siberia through Beringia and into North America. Thus, all North American wapiti would be a result of that colonization. The results of the study do not, however, support earlier proposals that Beringian wapiti were a distinct species or subspecies because of their larger body size and more complex antlers. The researchers concluded that these individuals reflect morphological variation within the same species.



Bayesian skyline plot derived from the analysis of modern and ancient wapiti sequences from northeast Siberia and North America. Only sequences with finite radiocarbon dates were included in the analysis, using a fixed clock and partitioned by gene region. The x-axis is in calibrated radiocarbon years BP, and the y-axis is the calculated effective population size using a generation time of 7 years. The dashed line represents median values, and the shaded area represents the 95% highest posterior density (HPD) limits.

Model for New World colonization

Barnes's team propose a three-stage model for North American colonization by wapiti.

- Initial colonization of northeast Siberia occurred before MIS 3, the period spanning 60–24 ka —beyond the range of reliable radiocarbon dating.
- These animals remained in the area throughout MIS 3, with some dispersion to areas farther south and west. Population size sharply declined during MIS 2 (ca. 24–11 ka), but showed no genetic discontinuity to indicate a local extinction.
- Wapiti migrated across the Bering Land Bridge and colonized Alaska around 15 ka, then expanded rapidly southward into the rest of North America. A gradient in radiocarbon dates supports the proposal that this wave of the migration included the ancestors of present North American populations.

Two important questions arise from the timing of faunal migration into North America.

- Given the long history of colonization by wapiti in northeast Siberia, why didn't the eastward migration begin earlier?
- What were the special conditions that allowed migration to proceed at 15 ka?

Earlier studies have suggested that competitive exclusion by two abundant large herbivores, mammoth and horse, might answer the first question, but the study's authors reject this proposal owing to the coexistence of mammoth, horse, and wapiti in Siberia during MIS 3 and their co-occurrence in many other Siberian Upper Paleolithic archaeological sites.

The environment of late-Pleistocene Beringia

Recent studies dispute earlier suggestions that the environment of late-Pleistocene Beringia was fairly uniform throughout the period. The area is now considered a more diverse environment that embraced a mosaic of biological communities. Steppe tundra with its mixed grasses shared space with shrub tundra and areas of larch and spruce forest with some birch and alder trees, providing ideal conditions for wapiti browsers.

For much of MIS 3 and 2, the colder, wetter climate of the Bering Land Bridge may have prevented the transit of moose and wapiti. Significant environmental warming around 17–18 ka, before human colonization, provided increased forage for browsers. Amelioration of climatic conditions thus likely invited migration after 15 ka.

Conclusions

The Barnes team's three-stage model of colonization for wapiti resembles the model derived from genetic data for human colonization of North America. Both models, for wapiti and humans, suggest expansion into northeastern Siberia during late MIS 3, where the populations remained until 15 ka and then rapidly expanded into North America. One interpretation could be that specialized human hunters followed migrating wapiti. But this ignores the presence of other large game in the area and the scant wapiti remains discovered at early archaeological sites. Evidence of wapiti taken as prey by human hunters increases after 14 ka and may reflect local extinctions of mammoth and horse. Indeed, tools made from wapiti antler are found in the earliest archaeological sites

continued on page 8

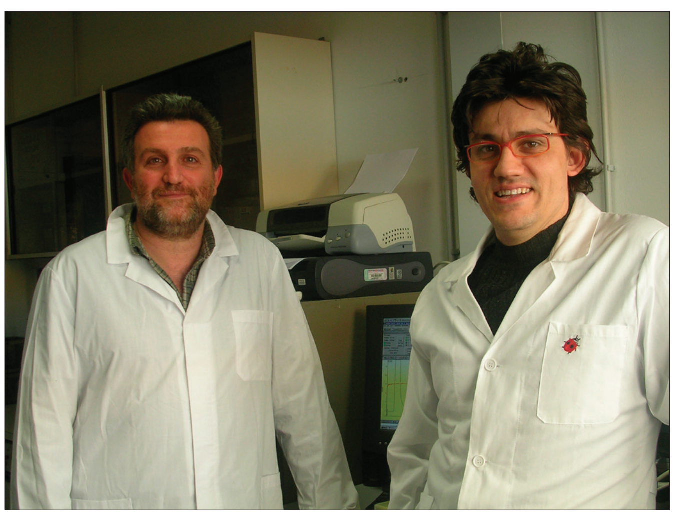
Tracking Paleoamerican Migrations with Mitogenomes

Collecting blood samples from members of a cheerful and cooperative Native American population.

ALESSANDRO ACHILLI

PRESIDENT CLINTON, in his announcement of the first sequencing of a human genome in 2000, said that it was "the most important, most wondrous map ever produced by humankind." At least part of the wonder is that your genome can be read as a literal map along which you can follow your ancestors back to their various homelands—ultimately back to Africa, the homeland of us all.

Alessandro Achilli and 17 other scholars from 10 institutions from Italy, Canada, and the United States are using the mitochondrial genomes, or "mitogenomes," of indigenous American Indians to trace the routes followed by their ancestors from Asia to North America. What they are learning is refining our understanding of the history of early migrations and challenging the most popular three-wave model for the peopling of the Americas as too simplistic.



ALESSANDRO ACHILLI

Torroni *(left)* and Achilli in their lab.

America's founding mothers

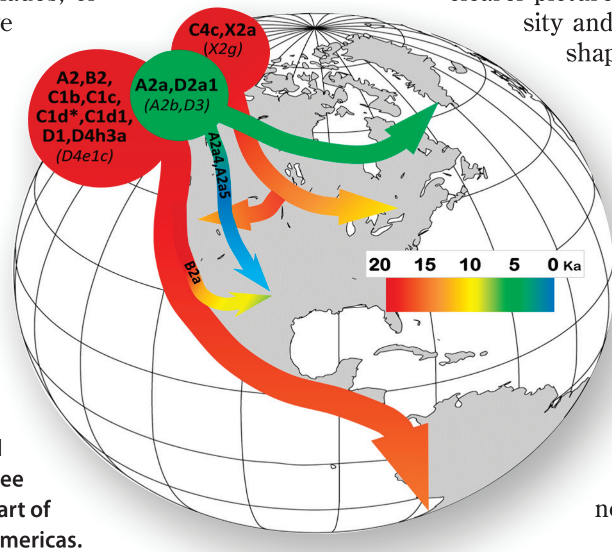
In addition to your nuclear DNA, the DNA contained in the nucleus of your cells that serves as your genetic blueprint, there are other sources of genetic information that offer clues to where you come from. One additional source is the DNA contained in the mitochondria, which inhabit the cytoplasm of your cells. Mitochondria are distinct organelles that serve as sources of energy for the cell. Apparently they once were entirely separate critters that at some point in the evolution of multi-cellular life became absorbed and turned into a useful part of the cell's machinery. Your mitochondria come to you from your mother's egg cell. The small contribution from your father's sperm cell is lost just after the egg is fertilized. Mitochondrial DNA (mtDNA) is a powerful tool for tracing your ancestry, but it can only follow your maternal lineage.

Another way to gain insight into genetic histories is to study the DNA of the Y-chromosome. The Y-chromosome is one of the two sex chromosomes. You get one sex chromosome from your mother and one from your father. You can get only X chromosomes from your mother, but either an X or a Y from your father. If you get an X from your father, then genetically you're a female. If you get a Y chromosome from your father, then genetically you're a male. As a result, only males have Y chromosomes; when geneticists study the Y chromosome they are therefore seeing only the male line of inheritance. Therefore it's complementary to (but not always concordant with) the genetic history provided by the mitochondrial DNA.

Previous studies of American Indian mitochondrial DNA have identified five basic haplogroups, or branches on the mtDNA family tree. These are designated by the letters A, B, C, D, and X. Since mtDNA is inherited solely from your mother, the letters signify the five founding mothers of the first Americans. When did they get here and where did they come from?

All five haplogroups—A, B, C, D, and X—are found in northeastern Asia, although haplogroup X is rare there. Haplogroup X is also found in Europe, and, because X is most common in American Indians on the northeastern coast of North America, some scholars have suggested that X came to America from Europe (**MT 28-2,** "Do Clovis origins lie in Paleolithic Spain?"). Other scholars, particularly geneticists, disagree with this interpretation (**MT 28-3,** "Alternative views of the Solutrean theory"). Other less-common Native American founder haplogroups have also recently been identified, several by the same Italian team.

Achilli and his colleagues estimate that the founders of all the mitogenomes they documented entered America between 15,000 and 18,000 years ago. One of the goals of Achilli and his team is to refine our understanding of where the various haplogroups originated and how they ended up where they are in the Americas, by looking at subclades, or smaller branches on each of these five main branches. Subclades represent daughters, or the many-times-great-grand-daughters, of those five founding mothers who moved off and established their own family dynasties, which gradually developed their own distinctive mitogenomes by accumulating unique mutations.



This map of the Americas shows the 16 mtDNA founder lineages and the three major associated migratory events. Founder lineages that haven't yet been sufficiently analyzed are italicized. Stealth arrows show two additional events: the recent southward spread of the Athapaskans (A2a4 and A2a5); and the major in situ expansion of B2a. Achilli and Torroni's team emphasize that the three migratory waves from Asia tell only part of the story of the peopling of the Americas.

ALESSANDRO ACHILLI

Those distinctive mutations occurred at a more or less constant rate. This means that you can use the amount of genetic difference between mtDNAs of different populations as a measure of the time that has elapsed since they separated. Moreover, groups that share distinctive mutations share some common history. Any group of such mtDNAs that can be shown to have a distinctive common genetic history is called a haplogroup.

Evaluating migration models with mitogenomes

Many previous studies of Native American genetic diversity concluded that there had been a minimum of three episodes, or waves, of migration from Siberia. Alessandro Achilli and his colleagues point out that most of these migration models were devised using only selected segments of mtDNA and that none have been tested "using the information in the entire mitochondrial genome [mitogenome]." Obviously, using the entire mitogenome gives you access to the entire genetic history for an individual rather than paragraphs or even chapters from that story.

Achilli and his team focused on "mitogenomes belonging to two haplogroups, known as A2a and B2a, which are characterized by peculiar geographic distributions." The A2 mtDNA haplogroup is found in varying proportions all across the Americas, but individuals in the A2a haplogroup occur only in Siberia, Alaska and in the American Southwest. The B2 haplogroup also is common throughout the Americas, but B2a is found only in North America south of Alaska.

Achilli and his coauthors report 41 new mitogenomes belonging to A2a and B2a. When combined with previously analyzed mitogenomes, their study included a total of 46 A2a and 38 B2a mitogenomes. They determined the geographic distributions of these haplogroups with the goal of gaining a clearer picture of Native American genetic diversity and the migration histories that have shaped their geographic distributions.

A2, in general, is abundant across the far north, from Siberia to Greenland. Both A2a and B2a share a peak in frequency in the American Southwest. Within that region, however, there are important differences. A2a is largely restricted to the areas occupied by the Athapascan groups, including the Navajo and Apache. B2a, on the other hand, is widespread throughout the region, including Mexico, but not Central America.

Origin and spread of B2a

Achilli and his colleagues determined that the B2a haplogroup arose at the end of the Pleistocene about 11,000–13,000 years ago. It experienced a period of population growth about 8,000–10,000 years ago.

Because B2a, which isn't found either in Siberia or in Central America, appeared relatively late compared with the estimated original peopling of the Americas 15,000–18,000 years ago, it's therefore clear that it evolved in North America. But where exactly?

Today the B2a haplogroup is found in the Pacific Northwest, the Southwest, and Mexico. Based in part on these distributional data, Achilli and his team argue that "it originated in the Pacific coastal regions from one of the local descendants of the ancestral B2 mitogenomes that had rapidly spread along the coast." In support of a Pacific coastal migration route for groups carrying B2a, they note that the Tsimshian on the Northwest Coast appear to be one of the earliest branches on the B2a family tree. Nevertheless, Achilli and his colleagues acknowledge that the alternative hypothesis, that B2a "entered the North American continent through the ice-free corridor . . . cannot be completely ruled out."

Origin and spread of A2a

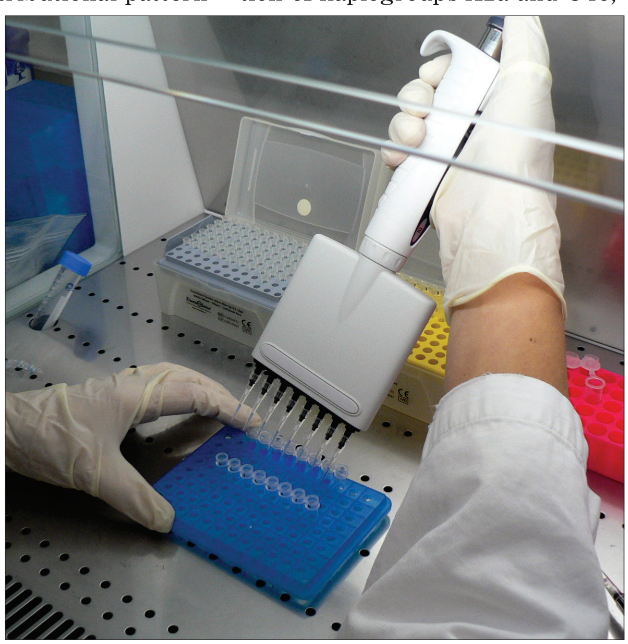
Achilli and his team determined that the A2a haplogroup arose 4,000–7,000 years ago. Two subclusters, A2a2 and A2a3, appeared in the Far North about 2,500 years ago. Two additional subclusters, A2a4 and A2a5, appeared in the Southwest about 1,000 years ago, or even later in the case of A2a4.

Besides being separated in time, the A2a and B2a haplogroups also have distinctive geographic distributions. The highest frequencies of A2a occur in Siberia, Alaska, and Greenland. A secondary concentration appears in the American Southwest, where it appears to be closely associated with the Athapascan groups of Apache and Navajo and neighboring groups they are known to have interbred with.

ALESSANDRO ACHILLI

Achilli *(left)* and Perego collecting specimens.

Achilli and his team infer from this distributional pattern that the A2a haplogroup originated in "one or more enclaves in Alaska" or perhaps "the westernmost part of the Northwest Territories of Canada," though they cannot completely rule out a Siberian origin. They link the A2a haplogroup with the Arctic Small Tool tradition, which appears earliest in the Kuzitrin Lake region of Alaska at around 5500 RCYBP. They further link the subbranches, A2a2 and A2a3, which are restricted largely to the Far North, to the "beginnings of Paleo-Eskimo culture." Achilli and his coauthors determined that the ancestral Paleo-Eskimo populations grew rapidly and, beginning about 4,000 years ago, expanded across the arctic region into both Siberia and western Greenland. Subsequently, less than 1,000 years ago, small groups of A2a, including the subbranches A2a4 and A2a5, migrated southward to become the ancestors of the Apache and Navajo. Achilli and his team infer this migration likely followed the eastern edge of the Rocky Mountains, although "a parallel Pacific coastal route is also a possibility."



ALESSANDRO ACHILLI

Processing DNA samples in the lab.

How many waves of migration?

Various migration scenarios for the peopling of the Americas have been proposed over the years. One popular theory proposes three waves of migration: The first wave of Paleoamericans gave rise to nearly all the indigenous peoples of the Americas south of Canada; a second wave was ancestors of Athapascan-speaking people, who are found mostly in Canada; a third wave became Eskimo and Aleut-speaking groups. More recently, however, geneticists have argued that all the genetic variability in the Americas could have come from a single wave of migration.

Achilli, Torroni, and their colleagues have attempted to gain a better understanding of the process of human movements into this hemisphere by closely examining the "entire mitochondrial genome" of a number of individuals belonging to the haplogroups A2a and B2a. They have determined that the vast majority of the variation in mitochondrial DNA across both North and South America comes from the initial wave of migration from Beringia, which appears to have followed the coastal route. Based on the molecular clock, this appears to have taken place about 15,000–18,000 years ago.

Achilli and Torroni's team also found evidence for a second, concomitant or slightly delayed, wave of migration that appears to have followed an inland route. It is marked by the introduction of haplogroups X2a and C4c, which were previously analyzed by the same team. Achilli and his colleagues think these haplogroups "might have been carried to North America by Beringian populations, which arrived through the ice-free corridor between the Laurentide and Cordilleran ice sheets" at about the same time people were making their way along the western coasts of America or possibly some time later. These later-arriving Paleoamericans were restricted to northern North America and had major genetic influence on a number of populations, including both Na-Dene and non-Na-Dene speakers (for instance, Algonquian speakers) now living in Alaska, Canada, and northern U.S.

Achilli and his colleagues see evidence in some Y-chromosome sublineages for a further wave of migration 4,000–7,000 years ago, when some groups, including members of the A2a haplogroup, spread from Alaska across the northernmost parts of Canada and Greenland. Actually, "the ancestral A2a carriers undertook both a back-migration to Asia and an eastward path along the circumpolar region of Canada and Greenland." This population expansion contributed to the formation of Paleo-Eskimos and also influenced the genetic makeup of the ancestors of modern Na-Dene.

Furthermore, later expansions occurred in the North, for instance, the one that gave rise to the Neo-Eskimo (Thule) groups and that probably brought the D3 (and perhaps A2b1) mtDNAs from Alaska to South Greenland only 1,000 years ago. At the same time, some Athapascan groups (Na-Dene speakers) started to move from northern Canada into the North American Southwest carrying variants of A2a. Achilli and his coauthors conclude that these data "provide a scenario of how different languages might be associated with distinctive gene pools."

The detailed analysis of variation in North American native mitogenomes confirms that "the arrival of the first American founders, when the territory was empty, left the greatest genetic mark" on indigenous North American Indians. On the other hand, it also makes clear that the genetic make-up of these people was reshaped by the influx of new immigrants from Beringia as well as by smaller-scale migrations and local mating patterns. All these factors combined make it clear that any hypothesis that attributes the peopling of the Americas solely to successive waves of migration from Asia should be viewed with suspicion. It was a much more complicated process than implied by a simple model of discrete waves.

–Brad Lepper

How to contact the principal of this article:
Alessandro Achilli
Dipartimento di Chimica, Biologia e Biotecnologie
Universita di Perugia
06123 Perugia, Italy
e-mail: alessandro.achilli@unipg.it

Suggested Readings

Achilli, A., U. A. Perego, H. Lancioni, A. Olivieri, F. Gandini, B. H. Kashani, V. Battaglia, V. Grugni, N. Angerhofer, M. P. Rogers, R. J. Herrera, S. R. Woodward, D. Labuda, D. G. Smith, J. S. Cybulski, O. Semino, R. S. Malhi, and A. Torroni 2013 Reconciling migration models to the America with the variation of North American native mitogenomes. *Proceedings of the National Academy of Sciences* 110(35):14308–313. Available online: http://www.pnas.org/content/110/35/14308.full

DeSalle, R. and I. Tattersall 2008 *Human Origins: What Bones and Genomes Tell Us about Ourselves*. Texas A&M University Press, College Station.

Mulligan, C. J., and A. Kitchen 2013 Three-Stage colonization model for the peopling of the Americas. In *Paleoamerican Odyssey*, edited by K. E. Graf, C. V. Ketron, and M. R. Waters, pp. 171–81. Center for the Study of the First Americans, Texas A&M University, College Station.

Wells, S. 2007 *Deep Ancestry: Inside the Genographic Project*. National Geographic, Washington, D.C.

Spread of Wapiti Mimics Human Migrations

continued from page 4

and chronicle the spread of the Clovis culture throughout the northern Great Plains.

The study demonstrates that because large mammals such as wapiti exploited the same ecological conditions as humans, fossil remains have significant potential to identify barriers to migration and serve as useful proxies when human remains are scarce. "This study pulled together various different technical specialties and specialists to address a question (radiocarbon, collagen analysis, oxygen isotope analysis of bone, ancient DNA, Bayesian modeling of dates, traditional archaeological and paleontological data)," Barnes explains. "In a field in which it is possible to spend a lot of time circling around the same small datasets, we identified a novel way of looking at colonization of the New World, which addresses why people might have crossed the land bridge at the particular time that they did."

As for why the archaeological record of late-Pleistocene Alaska reports extremely low human-population density and scarce human remains, Professor Barnes suspects the results may be skewed by the difficulty of excavating there. "In more logistically easy places to work (like Britain, for example, where you're never too far from a good road and a hotel), digging is not as problematic."

–Martha Deeringer

How to contact the principal of this article:
Ian Barnes
Earth Sciences Department
Natural History Museum
Cromwell Road, London SW7 5BD, UK
e-mail: i.barnes@nhm.ac.uk

Suggested Readings

Largent, F. 2007 Megafaunal extinctions revisited: The evidence from Alaska and the Yukon Territory." *Mammoth Trumpet* 22:3.

Meirav, M. et al. 2013 Supplementary Material. Faunal Record Identifies Bering Isthmus Conditions as Constraint to End-Pleistocene Migration to the New World: n. pag. Web.

Meiri, M., A. M. Lister, M. J. Collins, N. Tuross, T. Goebel, S. Blockley, G. D. Zazula, N. Van Doorn, R. Dale Guthrie, G. G. Boeskorov, G. F. Baryshnikov, A. Sher, and I. Barnes. 2013 Faunal record identifies Bering isthmus conditions as constraint to end-Pleistocene migration to the New World. *Proceedings of the Royal Society B: Biological Sciences* 281.1776 (2013).

Siddall, M., E. J. Rohling, W. G. Thompson, and C. Waelbroeck 2008 Marine isotope stage 3 sea level fluctuations: Data synthesis and new outlook. *Reviews of Geophysics* 46.4.

Part 2

The Cody Complex

All about bison hunting . . . and much more

MATTHEW HILL'S RESEARCH has left him with sometimes conflicting data that beg for more study. Today most of the scholarly debate about the Cody Complex is confined to bones and stones, which are merely material evidence. We know, though, that these people surely had a life broader than hunting and gathering. The truth, however, is that the social organization and worldview of Cody Complex peoples remain a large blank spot on the cultural map.

Prime bison country in Cody times: The Finley site, Wyoming.

The Cody Lifestyle: An Elusive Prey

Nevertheless, tantalizing glimpses of Cody lifeways do exist. Some 50 years ago, archaeologists digging the Renier site in northeastern Wisconsin described a cremation burial, an adolescent interned along a low sandy ridge overlooking the shores of modern Green Bay. Found associated with the burial were 11 points, all badly burnt—2 Edens, 8 Scottsbluffs, and what has been called a St. Charles/Thebes point. In another burial, this one from the Pope site in east-central Wisconsin, Eden points were found. These isolated cases shine a bit of light, albeit quite dim, on Cody funerary practices.

Cody artwork likewise has teased researchers, but examples are scarce. In 1979, researchers found a bison ulna at the Jurgens site in Colorado incised with a series of linear and geometrical engravings that occur in pairs and triplets across the lateral and medial faces. That same year at the same site, diggers found the only known example of a Cody pipe. Fashioned from a naturally hollow iron silicate concretion, the pipe was considerably polished from use. Although it's unclear whether the pipe was smoked for pleasure or to fill a ceremonial function, Knell and Muñiz note that it's evidence that pipe smoking dates to the Paleolithic period.

After the curtain lifted briefly to reveal snapshots of Cody burial habits, artwork and smoking habits, it dropped just as quickly, obscuring what remains to be learned from future site exploration. "We have almost no understanding of their spirituality or ideology," Knell and Muñiz candidly note in *Paleoindian Lifeways of the Cody Complex*. They attribute the current paucity of our knowledge to a lack of "pertinent analogies, artifacts and human remains," and they encourage researchers to work at enriching these databases. "Comprehending the Cody worldview obviously would improve our understanding of Cody lifeways as a whole," the authors emphasize.

Even with our sadly deficient knowledge, we can state with confidence today that people of the Cody Complex were supremely capable hunters who responded well to their environment.

It's encouraging to note that efforts are already under way to expand our knowledge of the Cody Complex. Devising the means to investigate a culture that lies 10,000 years in the past is a devilishly difficult task, but anthropologists Edward Knell of California State University, Fullerton, and Matt Hill of the University of Iowa believe that's what they've done. In what they describe as an almost "accidental" collaboration growing out of their doctoral dissertations, they have constructed a model they believe captures a clearer understanding of how late-Paleoindian people of the Cody Complex—a culture long identified with large bison kills on the Great Plains—skillfully and with remarkable foresight made use of the land they inhabited for two millennia beginning around 10,000 years ago.

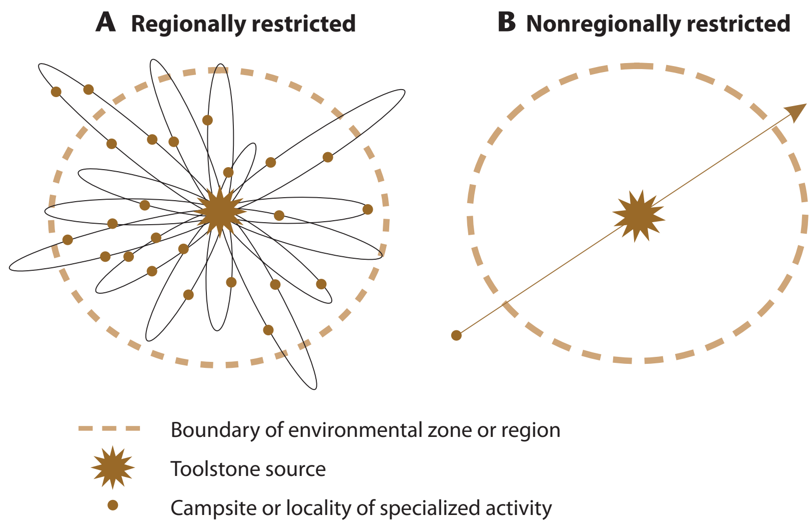
Harnessing the power of the computer to gauge the lifestyle of Paleoindian hunters

To many researchers, the widespread Cody Complex, associated with its type site near Cody, Wyoming (the Horner site), is one of the most important Paleoindian cultures in North America. Despite sometimes intense investigations, however, it remains poorly understood today.

Predictive modeling is the technique Knell and Hill use to weigh many interacting factors associated with the Cody Complex. Stated simply, their tool establishes interactive relationships between sets of variables and predicts probable outcomes—a process similar to the algorithm computer software uses to filter "spam" from e-mails. In the 1950s archaeologist Gordon Willey, working in the Viŕu Valley of Peru, laid the foundations for its use in archaeology. By investigating such contributing factors as slope, soil type, geology, proximity to water, geomorphology, and vegetation, he detected relationships between cultural remains and natural features. Willey's method has become increasingly popular over the years. Thanks to the omnipresent computer, it has become an enormously powerful tool.

To construct their predictive mathematical model, Knell and Hill amassed data on thousands of faunal bones and scores of stone tools and tool fragments collected from Cody Complex sites across the Great Plains. They then integrated with this data stew properties of three key environmental zones: foothills/mountains; plains/grasslands; and the alluvial plains of the northern Great Plains and Rocky Mountains. Herculean number-crunching calculations by the computer, which tweaks selected factors in turn and measures the effect on the outcome, yield an eye-opening portrait of Cody people. They are revealed as remarkably vibrant and dynamic hunters, clever and imaginative people accustomed to "making decisions based on how best to get their needs met."

Knell and Hill's findings, and a detailed description of the model, appear in "Linking Bones and Stones: Regional Variation in Late Paleoindian Cody Complex Land Use and Foraging Strategies," published in a 2012 issue of *American Antiquity*.



Land-use strategies practiced by Cody people. If the environmental region was rich in resources (A), the group would confine hunting forays to the region and return occasionally to the known source of toolstone to refurbish their toolkits. If the group, however, was passing through a relatively barren region (B), they would pause at a toolstone source only long enough to replenish their supplies before journeying on to richer regions. Some authorities believe Cody people were divided into two populations depending on which strategy they employed. Knell and Hill, however, believe all Cody people alternated between the two strategies depending on the particular circumstances prevailing.

AFTER EDWARD KNELL, ORIGINALLY PUBLISHED IN *AMERICAN ANTIQUITY* 77:1, PAGE 47.

A wider scope gives a clearer picture

The impulse to construct a predictive model, Knell and Hill explain, grew out of their frustration with earlier research, which invariably focused on individual Cody sites. All too often, they say, investigators overstretched by trying to "interpret the entire Paleoindian world based on one site."

Over the years archaeologists tended to group into two schools. One viewed Paleoindian people almost as single-dimension stick figures—opportunistic, highly mobile, and not very imaginative big-game hunters who roamed vast reaches of the Great Plains. Those in the other school regarded them as at times essentially semi-sedentary, broad-spectrum hunter-gatherers who remained tethered to a particular region of the foothills adjacent to the Great Plains, onto which they sometimes ventured to hunt bison. Often these distinctly different views were applied to Paleoindian cultures in general, not just to the Cody Complex.

But Knell and Hill thought it probably wasn't that simple, that there might be another way to see how some Paleoindian people, particularly Cody people, optimized use of the land. Perhaps, they hypothesized, Cody people alternated between the two lifestyles and adopted whichever promised the best results depending upon the circumstances at any given time.

Indeed, their model predicts and the data support two distinct patterns. In the resource-rich foothill mountain zone, they employed a regionally restricted land-use strategy for much of the year. They made only limited excursions, during which they relied on local toolstone, and they exploited both dispersed bison herds and small-bodied animals. Cody people in the resource-poor plains grasslands and alluvial valleys, on the other hand, didn't restrict their activities to a particular region. Instead they moved rapidly through regions, making many encampments over vast areas, and relied on natural sources for toolstone and sustenance, primarily bison.

The foothills-mountain area consistently produced higher yields—showed "higher caloric return rates"—particularly during the fall and winter than did the plains grasslands and alluvial valleys, Knell and Hill stress in their journal article. Although statistical variations are sometimes slight, they believe Cody people were sensitive to the difference and therefore moved their hunting activities accordingly, shifting to the foothills-mountains region to tap "abundant and predictable resources during the winter."

"I believe these were dynamic people who were flexible in their way of life," says Hill, "and they seem to have had a very successful way of life." The same group that may have hunted bison on the plains part of the time would at another time tap other resources in a foothill environment, perhaps staking out a territory and not traveling afar. What they did, and how and when they did it, might depend on the season or the circumstances. For Knell and Hill, this picture of a nuanced Paleoindian realm makes more sense than a Cody Complex neatly divided into two populations.

Marching to a new drumbeat

In reaching their conclusions, Knell and Hill attach no blame to prior researchers or their work. "We are not trying to say anybody, any prior researcher, was wrong," Hill explains. "The past researchers were our heroes. We are just trying to stand on their shoulders, to take the next step" by creating an empirical, verifiable tool, that of mathematical modeling. Previous approaches were often highly intuitive and less easy to verify and replicate through observation or experiment, which is a key principle of the scientific process. In other words, Knell and Hill took a different route to reach many of the same conclusions as their predecessors.

Prior researchers weren't "shooting from the hip," as some critics might conclude, Knell insists. They were using "good, solid intuition to derive assumptions about the way people should adjust land use in response to resource structure." Some of those assumptions proved equally as correct as those reached by Knell and Hill. The big difference here, says Knell, is that whereas "they derived assumptions, we derived quantitatively and theoretically grounded predictions about the way people should respond to variations in resource structure."

Where Knell and Hill depart from previous investigators of the Cody Complex is the use they make of the two datasets, bones and stones. Earlier researchers typically focused on only one component, bones or stones. Knell and Hill, on the other hand, link the two datasets to "infer subsistence and land-use patterns at the regional scale." By integrating and evaluating other variables, their theoretical model explains how calorie-maximizing hunter-gatherers "optimally adjusted their subsistence and land use to variations in resource structure at the regional level." Their model, in other words, shows how these Paleoindian people moved about the landscape to get the biggest bang for their buck.

Patches, a new wrinkle in Cody research

To determine more precisely how Cody hunter-gatherers responded to their environment, Knell and Hill added another layer of complexity to the mix of faunal and lithic variables in their mathematical model. Called "optimal foraging theory and temporal resource predictability theory," this specialized operative calculates the "patch-caloric return rate" for a "patch" of land. With this single index, it's possible to rank patches of land with respect to their resource productivity, from least to most productive relative to the amount of energy (calories) yielded per unit of foraging time invested, including time spent searching for game and processing a kill.

We would expect that Paleoindian foragers, given their knowledge of the environment, would select patches that yielded the highest rate of return and thus realize maximum gain with the least effort. That is precisely what Knell and Hill's predictive model confirmed. This means that Cody people likely returned more often to highly productive areas and stayed tethered to them longer; conversely, they would move more quickly through less-productive areas. The season of the year and availability of game could also influence their decision.

Considering lithic data in connection with faunal data, Knell and Hill were able to refine inferences regarding land use and foraging. For example, when Cody foragers settled for a long time in a productive resource zone in the foothill-mountain area, evidence shows they quarried large amounts of local toolstone and made and discarded considerable quantities of tools. When faunal data were applied to the predictive model, the results indicate that Cody foragers in this area hunted "small, dispersed herds of bison" while simultaneously sampling the region's rich diversity of other foods, thus increasing the breadth of their diets. Although big-game hunting was a valuable economic strategy for these people, they also exploited other animals and plants during peak hunting times in fall, winter, and summer, as the Knell and Hill land-use model predicts.

What the predictive model doesn't tell us

The predictive model has yielded a truckload of startling data. What it hasn't done is finally and absolutely resolve the argument between the dueling archaeological camps. It goes only so far as to verify that Cody hunters embraced two foraging strategies, one tailored toward hunting bison and medium-sized game, the other toward smaller game, primarily in the foothill regions.

"Personally, " says Knell, "I think we have only one people who were shifting in and out of specific foraging areas and activities as conditions dictated—the same people doing different things—but we really don't know." The data clearly indicate, however, that Cody land-use practices "varied predictably by environmental zone in accordance with the model projections."

Refining the model to pick up some of these unknowns remains a high priority. Both Knell and Hill are quick to concede that honing the model will take a lot more time.

Ideally, they want more questions answered and thus arrive at an accurate picture of Paleoindian life. "We want to know more about how these groups operate," says Knell. He foresees the need for detailed use-wear analysis of tools on known sites and any new sites that emerge, and for defining gender roles in hunting and general foraging activities. For example, were only young men bison hunters on the plains? Did the old, females, and children stay behind and perform other chores? Is there variability in toolkits for these people that would relate to specific duties under different circumstances? These are but a few of the questions that remain to be addressed.

Hill in the Plains of San Augustin, west-central New Mexico, 2006.

VANCE HOLLIDAY

What the predictive model does well

Knell and Hill consider their idea of combining the "bones and stones" a master stroke of their research project. "By looking at the lithics and the fauna together," Knell explains, "I think we get a much more nuanced understanding of what these people were doing and why they were doing it than we have seen before." No flora was included in their study, he notes, because there is "just not a very good floral record for this period. . . . They were undoubtedly using plants, but the way sites were dug and information collected, we just don't have that much data." Perhaps archaeologists will recover that data as new sites are opened.

They didn't dig any new sites for their research. Rather, the pair relied on museum collections and site data from a total of 33 previously examined Cody Complex sites on the Great Plains, largely for the benefit of clearly defined provenience. "Having these museum collections was invaluable to us," Hill said, despite the need to make sense of an often "messy and uneven record" where "some data were good and some not so good." The collections nonetheless gave them a chance to view past data through a fresh lens.

They had no shortage of bones to study. Overall, the collections contained 72,474 faunal specimens, including 65,237 bison bones and 6,490 bones from undetermined large-mammal species. Collection trays also contained the bones of other species, including rodent, beaver, deer, elk, turtle, bighorn sheep, marmot, wolf, fish, and birds—prima facie evidence that these Paleoindian populations had variety on their menu.

Does their predictive model provide a firm database for other studies? Knell thinks that "it provides a very good database, a model that could be used elsewhere," in different Paleoindian time periods, or in other settings such as the Mojave Desert, or in connection with later-period woodland cultures. He cautions, however, that it may be necessary to tweak the model to adapt it to different resources and environment.

Overall, Hill adds, it further advances our knowledge of First Americans studies because it keeps hammering home that "there is a lot of variability out there." It establishes a context for "what life was like in different areas," and it suggests that archaeologists should be looking for certain environments and specific land forms when they seek campsites or specific activity areas.

Knell doesn't hesitate to say the modeling exercise has given him a clearer picture of life in the early Holocene in general, and more specifically the way Cody people lived their lives. What he sees is "small hunter-gatherer groups of perhaps 15 or 20 people living together, moving around the land and living in the moment while thinking and planning ahead" to assure their survival. Maybe they are thinking about travel routes and when to set off on them so they will be in a specific environment for a late fall hunt. Or maybe they are looking toward settling in for the winter, moving into river valleys and foothills to forage for a variety of smaller game and wait out the winter cold, all the while looking ahead to the spring hunt, where to find the best rock to replace their tool kits. They may also be interacting with other Paleoindian groups, sharing information with them.

"These guys had a map in their heads of the larger area," Knell says, and they talked with others, looking for alternatives if no game was reported in a target area, or where to go to get the best fish, rabbits, or rodents to kill or edible plants to round out their diets. Being human, they also had to deal with other stresses of family life, a sick or injured family member—all the while trying to feed the group.

"These people," says Knell, "were sharp, smart, and clever. After all, they were us." MT

–George Wisner

Suggested Readings

Knell, E. J., and M. E. Hill, Jr. 2012 "Linking bones and stones: Regional variation in late Paleoindian Cody Complex land use and foraging strategies." In *American Antiquity* 77:1.

Exploring an Ethnolinguistic Melting Pot

Prehistoric California

IN PREHISTORIC CALIFORNIA, populations of speakers of different languages were settled remarkably tightly alongside one another. Linguistic diversity didn't develop to this extreme anywhere else in North America. What was unique about California? In searching for an answer to this question, the theory that environmental productivity—the richness of an environment in water, plant, and animal resources—predicts both the order of migration events and the population density of an area informs the work of anthropologists Brian Codding of the University of Utah and Terry Jones of California Polytechnic State University. What's more, the conclusions they draw from prehistoric California apply with remarkable accuracy to ethnolinguistics on a global scale.

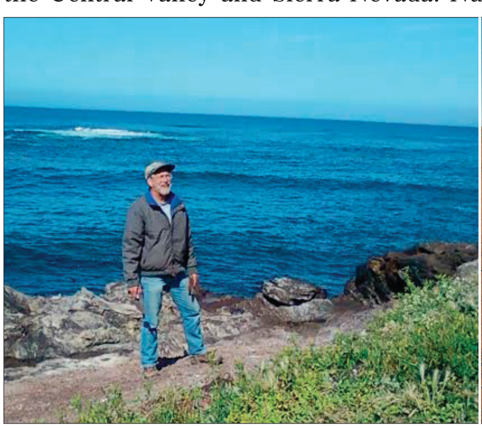
How ethnic diversity originates and expands

"Alfred Kroeber and colleagues started comparing languages to discern which were related to which," Dr. Jones tells us. "Once they discovered the ethnolinguistic mosaic particular to California, once they recognized it, the question has been, How did this come to be?" Researchers hypothesized pretty early on that "a lot of the equation was that you had people migrating into California at different times. Different points of origins, different cultures, one overlaying the other. If you think of it as a color scheme, you see over time new groups coming in."

That spatial distribution of ethnolinguistic groups reveals the origin and expansion of human ethnic group diversity. Using images of plant growth from the NASA Terra Satellite, Jones and Codding estimated the abundance of natural resources, which is a fundamental predictor of environmental productivity. By then correlating data from ecological and linguistic maps of prehistoric California, they discovered that the earliest settlers, who spoke languages from the Chumash and Yukian families, settled the most productive habitats along the Pacific coast about 12,000 years ago. These early colonizers occupied the most desirable habitats along the coast, whereas subsequent mid- to late-Holocene migrants settled in more marginal habitats. About 8,000 years ago, speakers of Hokan tongues and other groups occupied less-hospitable habitats in the Central Valley and Sierra Nevada. Numic speakers then settled the harsh deserts of southeast California and the Great Basin about 1,000 years ago. Dr. Codding illustrates as "a nice juxtaposition" the neighboring Great Basin, "a very different habitat. There's still variability in productivity, but it's much more homogeneous than California." The Great Basin, which includes parts of Oregon, Nevada, Utah, and southeastern California, has a uniformly arid habitat. As a result, almost all its early inhabitants spoke the same language, a form of Numic.

The richest environment attracts the first and the most immigrants

The underpinning of Jones and Codding's argument is the Ideal Free Distribution (IFD) model, a concept borrowed from behavioral ecology that's useful in analyzing prehistoric colonization and settlement. IFD states that migrants always settle the highest-ranking habitat until its suitability declines to the level of the next highest-ranking habitat. As populations increase through either migration or in situ growth, lower-ranking habitats fill in rank order. This progression adheres to the principle that the higher ranking the habitat, the



DAVID ZEANAH

BRIAN F. CODDING

Jones *(left)* in San Luis Obispo County, California; Codding screening sediments at an ethnoarchaeological project in western Australia.

greater its population density. It follows that the most suitable habitats, always occupied first, support the highest population densities and therefore contain the most language groups. This principle is confirmed by Joseph Birdsell, who demonstrates a strong correlation between the area occupied by Aboriginal tribes in Australia and the amount of rainfall it receives.

Codding notes that "in western North America, most of the productive areas are along the coast, particularly as you move up in latitude. You get more rainfall. The Northwest coast will be much more productive than some arid inland areas." Consequently, population density decreases from more productive to less productive regions. In an environment of uniform productivity, these migrations result in a cluster of many languages.

Other late-Holocene migrations altered this trend because increased sedentism and newly invented methods of storing food relieved a population's dependency on environmental productivity. Through successive migration events, incoming populations supplanted resident populations in both productive and less productive habitats, thereby fragmenting the earlier groups and creating one of the most diverse ethnolinguistic patterns in the Americas. The linguistic patchwork quilt of prehistoric California serves as a model for the rest of the world; its patterning is evident in the distribution of ethnolinguistic diversity worldwide.

How to account for the California phenomenon

Codding reveals two surprising discoveries he made during the course of his research into the language patterns of prehistoric California. "When I first started putting this together," he remembers, "I had these predictions. I thought there'd be interesting patterns emerging, but I didn't think the patterns would be so robust." When he reviewed the data and plotted population densities, his jaw dropped. "I was surprised," he remembers, "at how strong the patterning was. It was remarkable to me that these findings were so robust." Jones agrees with Codding: "If you look at a map of the distribution of native language families across North America, especially if it's color coded, what you'll see with respect to California is really dramatic. Across the rest of the continent you see these broad swatches with thousands of square miles where related languages were spoken. With California you have a crazy patchwork quilt of colors. It's startling!"

AFTER IVES GODDARD

The distribution of the populations of speakers of Native American languages reveals the imprint made on the continent by their distant colonizing ancestors. (Language families are indicated by names in all caps, languages by upper- and lowercase.) Abundant resource-rich environments in California account for its profuse, tightly clustered population groups. Insightful colonizers exploited ecological niches using strategies specialized to extract the greatest yield.

What Codding and Jones discovered was that unmistakable logic, not chance, governed successive migrations. "Groups took advantage of the best habitats that were available to them as they came in," says Jones. "In California we have tremendous environmental diversity, more so than any place else in North America, and so as a consequence, the cultural history of the place winds up reflecting that environmental diversity." Jones finds this overwhelming pattern intellectually satisfying because it is "relatively simple, and that's what makes it elegant."

Jones finds a thread of continuity running from modern California to prehistoric California, due in large part to the southern California physical environment. "People could access California from the interior and from the sea," he explains, "but lots of people in the world are coastal without this ongoing diversity. Parts of California, even today, pursue different economic opportunities in different areas."

Give credit to ancient peoples for know-how

What's the significance of this robust patterning? Jones says it points to human intelligence: "Historically, there's always been a tendency—we have more enlightened views today—to think of indigenous people as not being logical or intelligent, and what we've shown is that you can see absolute intelligence applied to decision making." Jones is speaking of all kinds of decisions—decisions consistent with mathematical predictions, evaluation of the productivity of the environment, from large-scale logic down to the logic of people making individual decisions. To him it's clear that the great preponderance of people making those choices were intelligent, rational thinkers. "No recent anthropologist has ever promoted the view that ancient people were not as intelligent as anybody else," he says, "but certainly even into the 20th century there was racism in California society that ancient people were somehow not intelligent. Even anthropologists have been guilty of not fully acknowledging that even the very first people to arrive were modern *Homo sapiens,* as intelligent as anyone living today. But they absolutely had to be because in so many ways it was more difficult for them." Anyone who harbors the illusion that we are innately superior to primitive peoples would be wise to heed the observation of physiologist-naturalist Jared Diamond, who notes the sea change that has swept New Guinea in his lifetime: "New Guineans whose fathers lived in the Stone Age now pilot airplanes, operate computers, and govern a modern state."

A competitive advantage bends the rules

There was one mystery, however, that Jones and Codding's model couldn't explain: How did speakers of Algic and Athabaskan languages, who arrived separately only about 1,000 years ago, replace the people who had long before settled in the lush coastal regions? This set of migrations, which didn't fit their predictions, is the second of Codding's surprising discoveries. "We've got this long record spanning 10,000 years that fit the predictions from this model," he recalls. "But the last two migrations [of Algic and Athabaskan speakers] are really different. More recent migrants look like they replaced people occupying places early on."

Resolving this anomaly led to the discovery that as a region became more crowded, later waves of migrants competed for the most suitable habitat regardless of whether the habitat was already occupied.

Archaeological evidence suggests that the more recent arrivals enjoyed advantages that enabled them to displace the original occupants. Codding discovered that these newcomers had a different and more efficient way of exploiting a principal resource of the local environment, salmon. They situated their dwellings close to streams and developed ways to store the salmon. Consequently, they were able to establish permanent residence. "They exploited this productive environment in ways that changed subsistence practices," says Codding. "All these groups were hunter-gatherers, but went about it in different ways."

Much of what Codding and Jones discovered in relation to human behavior and decision making points out the distinction between IFD (Ideal Free

◀ The environment in California ranges from mountains, plains, and river valleys to seashore and desert (the highest and lowest elevations in the lower 48 continental states lie within its borders). Diverse ecological niches rich in resources attracted groups of specialist hunter-gatherers. Each group adopted its own subsistence strategy and spoke its own language.

▼ Long Valley in Washoe County, Nevada, is typical of the semi-arid, resource-poor environment that characterizes the vast Great Basin, which was populated by generalist hunter-gatherers who practiced a catch-as-catch-can subsistence and spoke a common language.

JIM O'CONNELL

Distribution) and IDD (Ideal Despotic or Dominance Distribution model) dynamics. If the most suitable habitat was already occupied, then IFD dynamics were superseded by those of the IDD model: The occupants used exclusionary tactics to protect the resources from intruders. Expressing territoriality and adopting strongly sedentary permanence are examples of tactics used to discourage and, if necessary, defend against potential competitors. Resorting to IDD dynamics was most likely to occur when resources were concentrated and predictable. The IDD model is useful in archaeological studies to understand the emergence of hierarchies and intergroup resource competition.

Agriculturalists vs. hunter-gatherers

Exploring innovative subsistence strategies, researchers Thomas Currie and Ruth Mace discovered that the relationship between ethnolinguistic area and environmental characteristics is most pronounced in societies whose primary mode of subsistence is foraging; furthermore, ethnic diversity changes in a predictable way with changes in subsistence strategies and social organization. What Currie and Mace argue, in parallel with Jones and Codding's model, is that the distribution of certain language families is related to population expansion fueled by some competitive advantage.

From the perspective of niche construction, it follows that societies that rely on foraging and pastoral (animal herding) subsistence strategies are more vulnerable to changes in climate than agriculturists, who modify the environment in ways that buffer themselves from caprices in nature. For the majority of human history, foraging was the principal subsistence strategy. Until the advent of agriculture, the most important factor determining the distribution of ethnic groups, identified by language, was environmental productivity, which is determined by such climatic variables as precipitation and temperature. Agriculture lessened the impact of climatic fluctuations.

Trying to reconstruct ancient linguistic diversity

The anthropologist's job is hard, Codding admits, because "a lot of patterns in most of the world have been erased by agriculturalists. But looking at the archaeological record, we can predict how these pan out." Detecting ancient linguistic diversity is more difficult because it's almost impossible to infer language from material remains, but the same patterning across early America may be seen, and that provides a model with clues about where to look next. Codding notes that help was available in other places as well. "There have been a series of anthropologists over the last centuries who have mapped out spatial distributions of native populations recorded during European invasion. We have a series of different maps and scholars have tried to parse these out, helping us to see the distribution of languages across a region."

The next trick was to establish a timeline, to determine when and in what order speakers of different languages appeared in a region. Here Jones and Codding found it helpful to borrow ideas from a sister science, genetics. Geneticists look at modern and ancient populations; linguists estimate divergent states of language. "Both genetic and linguistic methods are similar," Codding says. "Instead of comparing the base pairs (A, C, T, G) of genetic structure, you're comparing different words as they relate to different cognates." The goal is to construct a linguistic phylogeny, much like a genetic family tree.

Jones explains that in California, "different languages emerged from a common language ancestor. The different patchwork of colors represents people entering North America with a common language and then for whatever reason, splitting, one group going one way and one group going another." After a language group arrived in California, it branched out. Jones cites as an example the Chumash language in Santa Barbara, a linguistic isolate that became a proto-language and evolved into seven daughter languages. Another example is Pomoan, which sired the languages north of San Francisco Bay. "Within Pomoan, there are multiple individual languages, and these get us back to the proto-language." With the aid of phylogeny, linguists can trace related languages to a family and sometimes trace related families to a linguistic stock.

Just as a geneticist tracks evolutionary changes on branches of a family tree, the linguist can often detect convergent and divergent trends in daughter languages. "There is some type of borrowing or convergence in the Great Basin region," says Codding. "One example of divergence is the Numic languages expanding out of Southeastern California and moving across the Great Basin. So you see languages in southeastern California that are probably parent languages to ones where I'm sitting out in Utah."

–*Katy Dycus*

How to contact the principals of this article:

Brian F. Codding
Assistant Professor
Dept. of Anthropology
University of Utah
270 S. 1400 E., Rm. 102
Salt Lake City, UT 84112
e-mail: brian.codding@anthro.utah.edu

Terry L. Jones
Professor of Anthropology and Chair
Dept. of Anthropology
Bldg. 47 Rm. 13D
California Polytechnic State University
San Luis Obispo, CA 93407
e-mail: tljones@calpoly.edu

Suggested Readings

Codding, B. F. and T. L. Jones 2013 "Environmental productivity predicts migration, demographic, and linguistic patterns in prehistoric California." Proceedings of the National Academy of Sciences. Edited by David H. Thomas, American Museum of Natural History, New York.

Currie, T. E., and R. Mace 2012 The evolution of ethnolinguistic diversity. *Advances in Complex Systems* 15.1-2, pp. 1–20.

Golla, V. 2011 *California Indian Languages.* University of California Press, Oakland.

Nettle, D., and S. Romaine 2002 *Vanishing Voices: The Extinction of the World's Languages.* Oxford University Press.

Elusive Crescentics

PORE THROUGH A COLLECTION of Paleoamerican lithic artifacts, and hidden among slews of projectile points, scrapers, and burins you may find a crescentic if you're lucky. These mysterious objects are distinctive in shape, striking in appearance—an expertly finished lunate or winged crescent rivals a gracile fluted point in beauty—and rare. Crescentics number no more than 5 percent of the artifacts from any site. Once widespread over much of western and northern North America and appearing in widely varying shapes, they found a place in the Paleoamerican and Archaic toolkit for more than 4,000 years. Crescentics disappear from the archaeological record about 8,000 years ago. Why they disappeared isn't clear, but neither is the reason they existed in the first place, because no one knows with absolute certainty what purpose they served.

The mystery that shrouds crescentics, and the many conjectured theories about their use, impelled University of Oregon anthropologists Madonna Moss and Jon Erlandson to explore this conundrum. Their starting point was the well-documented fact that crescentics are typically found in the context of ancient wetlands, which is why archaeologists have long suspected a connection between crescentics and waterfowl. Drs. Moss and Erlandson investigated ancient and modern bird activity in the Great Basin, the Canadian archipelago, eastern Beringia, and the prairie pothole region of Canada and the Great Plains. They weighed many possible functions of crescentics, taking into consideration all available ethnographic evidence on hunting waterfowl. Using an interdisciplinary approach, they drew on ornithology, genetics, molecular ecology, evolutionary biology, and paleoclimatology, as well as knowledge imparted by Canadian wildlife biologists.

Chipped-stone crescent from San Miguel Island.

K. HAMM AND JON ERLANDSON

The result of their labor is "Waterfowl and Lunate Crescents in Western North America: The Archaeology of the Pacific Flyway," published in the June 2013 edition of *Journal of World Prehistory*. Moss and Erlandson conclude that lunate crescents were likely used to procure large anatids rendered flightless in molt. (Anatidae is the waterfowl family that includes ducks, geese, and swans.). Their analysis provides a solid foundation for further research into crescentics, the under-recognized role of waterfowl in the hunter-gatherer diet, and innovations in lithic technology in response to changes in the composition of wildlife habitats.

An artifact with many faces

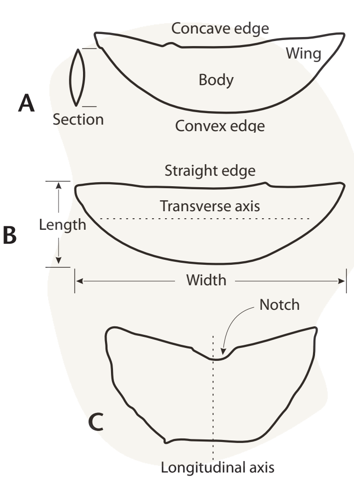
Crescentics are a member of the Western Stemmed Tradition. Generally 2½–10 cm long, their morphologies include lunate shapes (half-moon, crescent moon, and winged or butterfly crescents) and the catch-all group known as eccentrics, which include notched crescents. Eccentrics sometimes appear zoomorphic in design, thanks to spurs that suggest stylized arms, legs, and head (think Santa Fe bear carvings.) Some bizarre specimens could pass for jigsaw-puzzle pieces. The puzzling array of shapes among crescentics probably indicates a variety of functions.

In their paper, Moss and Erlandson focus on lunate crescents, which have been found in Washington, Oregon, Wyoming, Utah, Idaho, California, Nevada, New Mexico, and Colorado. Almost without exception, every site that has yielded crescents was once a wetland environment—lake, marsh, estuary, or island. Because of this association with water and, by extension, with waterfowl, Moss and Erlandson adopted a resource-focused approach to explore why crescents disappeared about 8000 CALYBP.

The changing face of waterfowl distribution

Having decided to focus on waterfowl that likely figured prominently in the hunter-gatherer diet, Moss scrutinized the migratory patterns and breeding habits of modern-day anatids. Today a number of key taxa breed almost exclusively at very high latitudes: tundra swan, greater white-fronted goose, snow goose, and Ross's goose. Not only do these species currently breed in the High Arctic, an area that was under ice until the early Holocene, it's highly likely that in pre-Archaic times they bred in the Great Basin and California. These areas, in fact, may then have been home for many species of waterfowl.

"There aren't a lot of biogeographical data for birds that aren't either facing extinction or posing a nuisance," says Moss. Generalizing across

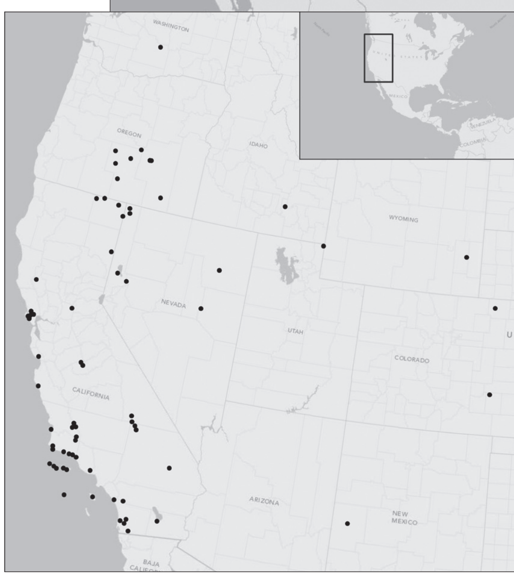


Crescents: A, Type I, quarter-moon; B, Type II, half-moon; C, Type III, butterfly.

all species with limited information isn't easy. "When you're doing this kind of research you hope you'll be able to fill in all the gaps in these various lines of evidence, and that's not possible. The kinds of questions wildlife biologists are asking aren't the same kinds of questions that are relevant to an archaeologist." Moss acknowledges that it's impossible to prove any hypothesis regarding prehistoric bird-migration routes. The relevant data, however, that Moss collected from paleontology, molecular biology, and current geographic distributions establish a solid framework for the clear, workable explanations presented in the paper.

PREPARED BY JULIA KNOWLES, AFTER JOHNSGARD 2010

The "Prairie Pothole" region in central ▶ Canada today and the extent of pluvial lakes in the Great Basin during the terminal Pleistocene. Moss and Erlandson believe the Great Basin may have been richer in migratory waterfowl during the late Pleistocene when lakes and marshes were at least ten times more extensive than they are today.



PREPARED BY JULIA KNOWLES

Archaeological sites that have yielded ▼ chipped-stone crescents.

Sites with crescents

Moss and Erlandson's paper presents basic data on bird assemblages at many sites. The Weed Lake Ditch site, for example, on the shore of pluvial Lake Malheur in Harney Basin, Oregon, is well stratified. Coots constituted 71% of the assemblage of waterfowl remains, but only one crescent was found. On the other hand, sites on the Northern Channel Islands off the coast of southern California were a treasure trove. CA-SRI-512, which dates as old as 11,750 CALYBP, yielded over 25 crescents along with stemmed points and bone tools. The faunal assemblage included waterfowl, seabirds, near-shore fish, seals, and a small percentage of marine shell. At Daisy Cave, a crescent was found in shell middens dating to 10,000–8600 CALYBP.

Beth Smith, an archaeologist with the Nevada Department of Transportation, was thrilled to read about her favorite subject. "It's neat to see bird bones so closely associated with crescents," she says, and was particularly impressed by the wide range of data involved. She would love to see more research done at sites in her home state of Nevada. Unfortunately, many Great Basin crescent sites are pluvial in context, therefore ephemeral in nature. Because they aren't the faunal time capsules rockshelters tend to be, it's difficult to infer from their scant evidence how crescents were used.

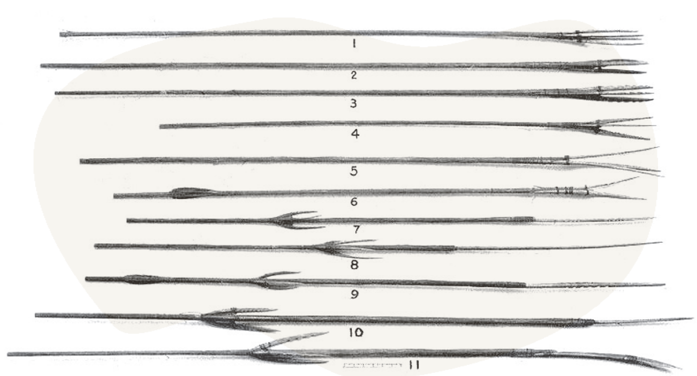
Function and operation: ethnographic examples?

Some archaeologists define crescents as projectiles, others as scrapers or cutting tools for processing meat or plants. Originally it was thought they were tools used for surgery or tattooing, or possibly served as gravers. Absent an explicit ethnographic example, archaeologists can't say with certainty whether the crescent used as a tool was handheld or hafted, or indeed whether it was a tool at all. A long-held theory that crescents were hafted as dart tips has led to the alternative name "transverse point." Since the advent of use-wear and residue studies, however, inconclusive results have clouded the hafting theory. Moss and Erlandson's paper suggests ethnographic possibilities.

Moss cites a fascinating book, *Hunting with the Bow & Arrow,* published in 1923, in which author Saxton Pope gives detailed accounts of lore he learned from Ishi, the last surviving Yana Indian. In the book is an illustration of a metal "crescent bird point," but no description of the point or its use. Moss allows that "it's not a perfect analog but it's a possibility of how stone crescents may have functioned." It's frustrating for Moss that this illustration of a metal analog is the best ethnographic example of the stone crescent used as a transverse point.

Thoughts on the crescent used as a projectile point

For success in hunting waterfowl, anthropologist Eugene Hattori

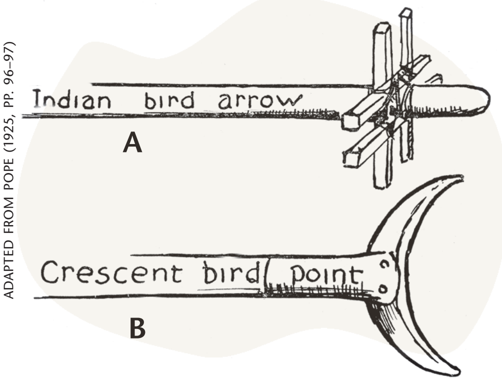


Spears used by Bering Strait Eskimos to capture birds. Spears 7–11 are made of a long point of bone, ivory, or deer antler, serrated on one or both sides and hafted to a wooden shaft 4–6 ft long. About a third of the length from the butt, points of bone, ivory, or antler are lashed in place with their sharp points extending obliquely outward. E. W. Nelson reports that "the object of the three prongs on the shaft is to catch the bird by the neck or the wing when the point may have missed it."

of the Nevada State Museum tells us it’s important to stun the bird. Waterfowl can survive an arrow through the neck because a dart point may miss their small vital organs. Archers today stand a better chance than did their predecessors of downing a large bird because arrowheads are commercially available that have both blunt and sharp barbs for “shock and rip” action; blunt barbs are intended to inflict massive tissue damage and prevent the arrow from passing through the prey.

Smith, although not prepared to dismiss absolutely the possibility that crescents were hafted, nevertheless remains dubious about the efficacy of the crescent as a projectile point. She once did a study where she tested specimens for flatness. She found that “the ends are twisted on over 30 to 40 percent of them. They weren’t designed to be thrown.”

ADAPTED FROM POPE (1925, PP. 96–97)



Two bird arrow tips illustrated by Saxton Pope. A, an ethnographic Native American arrow with blunt tip and latticework designed to broaden the impact area; B, a historical metal-tipped lunate arrow point similar to early chipped-stone crescents.

Moss, however, knows of a graduate student who designed a crescent-tipped projectile and became proficient with it, but the California Fish and Game department denied him a license to hunt waterfowl with it. She recalls that “the projectile spun when it flew.” She believes the perfect subject for a thesis would be “developing and testing different versions with or without birds, using arrows, atlatls, hand throwing. . . . That would be something I’d love to see somebody try.”

Madonna Moss.

Well, she’s in luck. Mike Lenzi, an archaeologist who specializes in Great Basin Paleoindians and experimental archaeology, and a master’s candidate at the University of Nevada at Reno, is completing his thesis on crescents this year. He argues that twisted and curved concave margins of crescents don’t significantly affect their accuracy. In his experience, he says, “I have seen numerous projectile points with remnant longitudinal curves from flake blanks that we have jokingly referred to as ‘for shooting around corners,’ yet we still know them to be projectile points.” The premise of his thesis is that crescents were designed for a specific task; “whatever that task may be, crescents should perform that task better than the technological alternative.” He compares crescents to unmodified flakes for use as scrapers and knives, and to Western Stemmed Tradition projectile points for use on darts. “Some early experiments have suggested that crescents are not significantly inaccurate,” he says, “and with my refined dart designs and a more experienced atlatlist I expect them to be fairly accurate.“ He plans to haft the crescent in two configurations, first with the wings facing forward in the direction of flight, then backward. Testing will be done in two stages, the atlatl thrown first at a bulls-eye target to calculate accuracy, then over a body of water to see if an advantage is gained by skipping along the surface. Moss and Erlandson’s paper alludes to this latter technique, which was used effectively by Inupiat and Yup’ik hunters of the Bering Strait. Whereas a spear thrown from overhead mimics a swooping raptor and causes swimming fowl to dive instantly, a spear skimming along the water confuses the bird and frightens it into immobility.

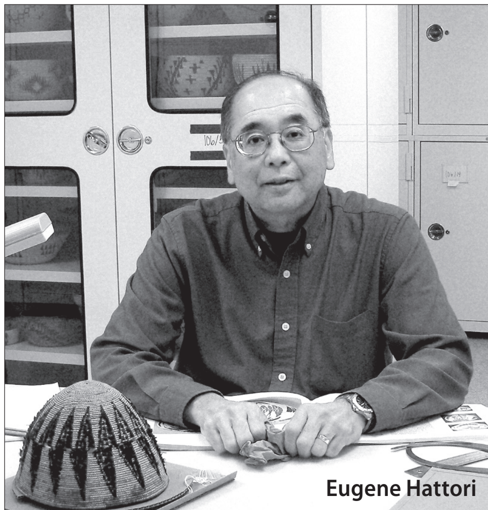
Another possibility: the crescent as a thrown weight

Another ethnographic comparison Moss explores is the bola, which consists of two or more stones, usually no larger than a chicken egg and grooved for securing to the end of a cord or thong. In historic times heavy bolas were used for hunting large animals in open country. The Inuit used a lightweight bola called a *qilumitautit* for hunting flying waterfowl. It consisted of several bone weights about 3¾ cm in diameter, attached to the end of several strings of sinew with a quill at one end to prevent sinking. Whether crescents could be used this way is a question that Moss believes could be addressed experimentally.

Smith sees several problems with attempting to cast crescents in this role. For one thing, she isn’t convinced they have enough mass. “Even if you’re throwing a net,” she reminds us, “it’s a weighted thing.” How to reliably tie the crescent in place is another problem fraught with difficulties. The crescent should be grooved for non-slip tying, a feature she has never seen. Moreover, she points out that the sharpened margins of the crescent would abrade sinew over time. She adds that many crescent specimens have random margin grinding, a flaw she attributes to the practice common before about 8000 CALYBP of reshaping broken tools into new tools. If a big stemmed point failed, for example, a toolmaker might reshape a piece for use as a crescent. Then the margin of the crescent might be smooth or rough, depending on where the parent tool broke. She further notes that crescents in an assemblage are usually made either of local toolstone, or of the same toolstone from a distant source as all the other tools. For Smith, this supports her contention that “crescents were made out of things you were throwing away, or just with what you had very locally.”

Was the crescent an ad hoc tool? If it was difficult to predict exactly when and where molting anatids would be available as prey, perhaps crescents were made on the spur of the moment as the need for them arose.

Moss and Erlandson also suggest, based on historical observations of Inuit hunters, that crescent-tipped spears may have been used to herd flightless birds in molt into holding pens for processing. Hunting waterfowl in this manner is illegal today, but it was once common practice.



Eugene Hattori

NEVADA STATE MUSEUM

Crescents and waterfowl: summing up

During the late Pleistocene and early Holocene, waterfowl were plentiful in the Far West where they bred and molted. There may have been millions of these sitting ducks (pardon the pun) available for easy procuring every season. Since the flightless time was only about a month, the crescent may have been a seasonal tool, which would explain its relative rarity in assemblages.

Beth Smith

DEPARTMENT OF TRANSPORTATION PHOTOGRAPHER: JULIE DUEWEL

Was crescent technology abandoned by hunter-gatherers because waterfowl abandoned their territory? Moss proposes that "as the climate in the Canadian archipelago became milder and the Great Basin increasingly arid, birds were able to breed at high latitudes free from human interference during the mid-Holocene . . . before people settled the high arctic." Lunate crescents used to hunt birds would therefore no longer be needed in the Great Basin.

Did the people that created and used crescents die out or blend with another culture? Was the crescent replaced with something that did the job better, faster, safer? At this point no one can say for sure. Moss and Erlandson chose to attack the problem sideways, examining not just the tool itself but the environment in which it was created and used. They looked at the continent as a whole, with its documented climate changes and the ripple effect on the lives of hunter-gatherers and consequently their toolkit.

Mike Lenzi

Moss wants people to consider human lifeways as "a very real factor influencing bird behavior." She hopes in the future archaeologists will pay more attention to avifaunal assemblages from this time of transition. It would help, she says, if people were to think of birds "not just as local resources but as animals that are moving through many ecosystems and to think about the implications of which bird is found where." She is optimistic that other researchers will use their paper as a springboard. "This article is filled with what I think are a lot of interesting ideas," she says honestly, "but I would not claim to have proven a lot of these things. I am putting them out there for others to investigate and examine." MT

–Dale Graham

How to contact the principals of this article:

Madonna Moss
Professor of Anthropology
University of Oregon
308 Condon Hall
1218 University of Oregon
Eugene, OR 97403
e-mail: mmoss@uoregon.edu

Eugene M. Hattori
Curator of Anthropology
Nevada State Museum
600 N. Carson St.
Carson City, NV 89701-4004
e-mail: ghattori@nevadaculture.org

Beth Smith
Nevada Department of Transportation
Environmental Division
1263 S. Stewart St.
Carson City, NV 89712
e-mail: BSmith2@dot.state.nv.us

Mike Lenzi
Master's student, University of Nevada, Reno
Far Western Anthropological Research Group, Inc.
1664 N. Virginia Street
Reno, NV 89557-0096
e-mail:mrlenzi@hotmail.com

Suggested Readings

Dincauze, D. F., and V. Jacobson 2001 The birds of summer: Lakeside routes into Late Pleistocene New England. *Canadian Journal of Archaeology,* 25, 121-126

Fiedel, S. J. 2007 Quacks in the ice: Waterfowl, Paleoindians, and the discovery of America. *Foragers of the Terminal Pleistocene in North America,* R. B. Walker & B. N. Driskell (eds.), (pp. 1–14) Lincoln: University of Nebraska Press.

Moss, M. L., and J. M. Erlandson 2013 Waterfowl and lunate crescents in western North America: The archaeology of the Pacific Flyway. *Journal of World Prehistory* DOI 10.1007/s10963-013-9066-5.

Nelson, E. W. 1899 The Eskimo about Bering Strait, 18th Annual Report of the Bureau of American Ethnology, for 1897–98, Government Printing Office, Washington, DC, pp. 19–526

Pope, S. T. 1925 *Hunting with Bow and Arrow.* G. T. Putnam Sons, New York. Online version available at The Archery Library, www.archerylibrary.com